Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Space Exploration Holdings, LLC	)	
	)	
Application for Modification of	)	File No. SAT-MOD-20200417-00037
Authorization for the SpaceX NGSO	)	
Satellite System	)	
	)	

PETITION TO DENY AND COMMENTS

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PETITION TO DENY AND COMMENTS

I. INTRODUCTION AND SUMMARY.

Kuiper Systems LLC, a wholly owned subsidiary of Amazon.com Services LLC (collectively, "Amazon"), submits the following petition to deny and comments on the above-referenced application of Space Exploration Holdings, LLC ("SpaceX") seeking approval to redesign its satellite system via a modification of authority (the "Third Modification").[1]

SpaceX's Third Modification should be denied as contrary to the public interest in space safety. SpaceX seeks to lower 2,824 satellites as much as 765 kilometers and operate them with wide orbital tolerances such that their trajectories will overlap each other and the operating altitudes of Amazon's earlier-filed non-geostationary satellite orbit ("NGSO") fixed-satellite service ("FSS") constellation.[2] Amazon's analysis of the Third Modification shows the addition

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[1] Space Exploration Holdings, LLC Application for Modification of Authority, IBFS File No. SAT-MOD-20200417-00037 (filed Apr. 17, 2020) ("*Third Modification*").

[2] *See* Kuiper Systems LLC Application for Authority to Launch and Operate, IBFS File No. SAT-LOA-20190704-00057 (filed July 4, 2019) ("*The Kuiper System Application*"). The magnitude of this change has also been recognized by DISH, who noted that the Third Modification would be a "massive reconfiguration of SpaceX's system" and lead to its constellation "bearing little resemblance to the system the FCC first authorized in 2018." Ex Parte of DISH Network L.L.C, IBFS File No. SAT-MOD-20200417-00037, at 2 (filed June 16, 2020) ("*DISH Ex Parte*"). In coming to that conclusion, DISH noted that the modification would "[s]tack the orbital shells with as little as ten kilometers of separation between them." *Id.*

of 1,240 SpaceX satellites at various orbital altitudes when combined with the Kuiper System's 784 satellites at 590 km results in an average of 509 daily conjunction events of close approach distance less than 1 km between the two constellations. This is more than an order of magnitude increase when compared to the Kuiper System's expected thirty-two daily conjunction events due to the existing orbit debris catalog. This increase in the number of conjunction events harms the public interest by creating new collision risks and potentially impacting service to customers. Denial of the Third Modification is therefore warranted.

Additionally, the relocation of these SpaceX satellites would negatively impact the interference environment for the Kuiper System and other NGSO FSS systems by increasing the number, duration, and impact of interference events. This impact on the interference environment renders competition more difficult and deters investment.[3] Accordingly, following resolution of space safety concerns warranting denial, the Federal Communications Commission ("FCC" or "Commission") should only consider the entire SpaceX constellation as part of the NGSO FSS processing round initiated on March 24, 2020 (the "2020 Processing Round").[4]

II. THE FCC SHOULD DENY SPACEX'S THIRD MODIFICATION BECAUSE IT RISKS SIGNIFICANT HARM TO SPACE SAFETY.

A. Available data regarding the functionality of currently operating SpaceX satellites evidences significant reliability concerns.

Satellites that fail in orbit create an increased risk of orbital collision and occupy physical space that other operators could use to deploy service to the public; additionally, failed satellites

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[3] *See Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, Report and Order and Further Notice of Proposed Rulemaking, 32 FCC Rcd 7809, ¶ 61 (2017) ("*NGSO FSS Order*").

[4] *See* Satellite Policy Branch Information, Cut-Off Established for Additional NGSO FSS Applications or Petitions for Operations in the 10.7-12.7 GHz, 12.75-13.25 GHz, 13.8-14.5 GHz, 17.7-18.6 GHz, 18.8-20.2 GHz, and 27.5-30 GHz Bands, Public Notice, Report No. SPB-279, DA 20-325 (Mar. 24, 2020) ("*March 24, 2020 Processing Round PN*").

do not have the ability to maneuver to mitigate space safety concerns.[5] SpaceX has represented to the Commission that its system would have a low rate of in-orbit failure.[6] SpaceX's Third Modification also indicated that "the success of the deployment of its first 362 satellites" supports the proposed system reconfiguration.[7] However, data available regarding SpaceX's currently deployed satellites do not appear to support these assertions.

On May 6, 2020, the International Bureau requested data regarding "whether any of the satellites launched to date have permanently lost maneuver capabilities at an altitude above the injection altitude."[8] SpaceX responded that 6 of the 60 satellites launched in the initial v0.9 tranche lost such maneuverability at altitudes ranging from 400 km to 552 km at that time.[9] Further, SpaceX indicated that 6 of the v1.0 satellites lost maneuverability at altitudes ranging from 383 km to 550 km (360 v1.0 satellites had been launched at the time of SpaceX's response).[10]

A month later, SpaceX's 2020 Annual Report shows that 9 v1.0 satellites that reached the operational altitude of 550 km lost maneuverability and required passive de-orbit, and that SpaceX actively de-orbited 5 additional satellites, at least some of which were "not performing optimally."[11] This indicates that up to 14 of the 478 v1.0 satellites SpaceX launched in the year-long period included in the 2020 Annual Report, approximately 3%, either failed or were in the process of failing; moreover, the 14 satellites indicated in the 2020 Annual Report included 3

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5 *See* Part II.B, *infra*.

6 *See, e.g.*, *Third Modification*, at 3 (calling a satellite failure in orbit an "unlikely event").

7 *Id.*

8 *See* Letter from Jose Albuquerque, Chief, Int'l Bureau, FCC, to William M. Wiltshire, Counsel, SpaceX, at 1 (May 6, 2020) ("*IB Letter*").

9 *See* Response to FCC Information Request of Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20200417-00037, at 4 (filed May 15, 2020) ("*SpaceX Response*").

10 *See SpaceX Response*, at 4.

11 Letter from William M. Wiltshire, Counsel to SpaceX, to Marlene H. Dortch, Secretary, FCC, at 1-2 (June 23, 2020) ("*2020 Annual Report*").

satellite failures that were not listed in the SpaceX Response filed only five weeks earlier,[12] indicating that reliability remains an ongoing problem for SpaceX's satellites. In addition, it appears that some SpaceX satellites have not yet achieved their target orbital altitude, and they may be undergoing a significant rate of orbital decay.[13]

Finally, SpaceX satellites maneuver autonomously,[14] which, if done without warning and screening, makes it difficult for other system operators to predict the positions of SpaceX satellites and react accordingly. The Commission must closely review SpaceX predictive ephemeris and covariance information, as well as information sufficient to evidence that SpaceX's collision avoidance maneuver planning addresses conjunction risks accurately and in a timely manner. The available data evidences significant reliability concerns.

B. SpaceX's proposed flight parameters create significant risks of collisions.

The Commission should also review the data regarding the operational impact imposed on other NGSO FSS systems by the Third Modification, especially in light of the questions posed above regarding reliability of existing SpaceX satellites. Increasing the daily conjunction events of close approach distance less than 1 km creates risks and potentially impacts service to customers.

SpaceX originally requested, and the FCC granted, authority to operate 4,425 Ku/Ka-band satellites at orbital altitudes between 1,110 km and 1,325 km.[15] Subsequently, SpaceX sought to

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12 *Compare SpaceX Response* at 5, Table 2 *with 2020 Annual Report* at 2, Table 1 (showing three additional failure altitudes in *2020 Annual Report* not reported in *SpaceX Response*).

13 *See* historical TLE data obtained from https://www.space-track.org/ (accessed June-July 2020).

14 *Third Modification*, at 11 (noting SpaceX has taken "steps to autonomously avoid non-propulsive systems").

15 *See* Space Explorations Holdings, LLC, Application for Orbital Deployment and Operating Authority, IBFS File No. SAT-LOA-20161115-00118 (filed Nov. 15, 2016) ("*SpaceX*

modify that authority to relocate 1,584 of those satellites to an altitude of 550 km and to reduce the total number of satellites to 4,409,[16] which the Commission granted.[17] Now, in this Third Modification, SpaceX seeks to reduce the total number of satellites by 1 and relocate the remaining 2,824 satellites to altitudes ranging from 540 km to 570 km (with a +/- 30 km orbital variation).[18] This significant change in parameters will have a deleterious effect on space safety.

As shown in Figure 1, prior to this Third Modification, the SpaceX satellites authorized to operate at 550 km would not have overlapped with the Kuiper System. The Kuiper System's satellites orbiting at 590 km, 610 km, and 630 km are designed to maintain an orbital tolerance to within +/-9 km and avoid any physical overlap with SpaceX satellites at 550 km,[19] even considering SpaceX's +/- 30 km orbital tolerance.

SpaceX's latest iteration of its NGSO FSS constellation would stack the system's 4 orbital shells ten kilometers apart at 540 km, 550 km, 560 km, and 570 km.[20] These orbital shells would nominally position SpaceX's highest orbital shell just 20 kilometers below the Kuiper System, which proposes a constellation of 3,236 satellites positioned in orbital shells at 590 km, 610 km,

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Application"). *See also Space Exploration Holdings, LLC*, Memorandum Opinion, Order and Authorization, 33 FCC Rcd 3391, 3392, 3405 (2018) ("*SpaceX Grant*").

16 *See* Space Explorations Holdings, LLC, Application for Modification of Authorization, IBFS File No. SAT-MOD-20181108-00083 (filed Nov. 8, 2018) ("*First Modification*").

17 *See Space Exploration Holdings, LLC*, Order and Authorization, 34 FCC Rcd 2526 (2019) ("*First Modification Grant*"). SpaceX also filed a second modification. *See* Space Exploration Holdings, LLC, Application for Modification of Authorization, IBFS File No. SAT-MOD-20190830-00087 (filed Aug. 30, 2019) ("*Second Modification*"). This modification did not affect orbital altitude. *See id.*; *see also Space Exploration Holdings, LLC*, Order and Authorization, 34 FCC Rcd 12307 (2019).

18 *See Third Modification*, at 3, 9.

19 SpaceX's orbital shells after its First Modification were 550 km, 1110 km, 1130 km, 1275 km, and 1325 km. *See SpaceX Application*, at 6; *First Modification*, at 2.

20 *Id.* at 4.

and 630 km.[21] However, SpaceX has stated that "as with its current constellation, apogee and perigee will be maintained to within 30 km, and inclination will be maintained to less than 0.5 degree of the respective target values."[22] With this orbital tolerance, SpaceX's highest orbital shell of 570 km, containing 720 satellites, and SpaceX's 560 km shells, containing 520 satellites,[23] would overlap with Amazon's orbital shell of 590 km, containing 784 satellites, as shown in Figure 2.[24]

As such, the Third Modification implicates safety concerns that the prior modifications did not.[25] While FCC rules do not prohibit applicants from seeking overlapping constellations, the impact on space safety is a factor in the FCC's public interest analysis.[26] The FCC has stated that

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21 *The Kuiper System Application*, at 1.

22 *Third Modification*, at 3.

23 *Id.* at 4.

24 *The Kuiper System Application*, at 2. Additionally, Swarm and Spire, as well as Planet Labs, have significant numbers of satellites whose altitudes will also overlap with SpaceX's under the Third Modification. *See Swarm Technologies, Inc.*, Memorandum Opinion, Order, and Authorization, 34 FCC Rcd 9469 (2019); *Spire Global – Grant In Part, Defer in Part*, IBFS File No. SAT-PDR-20190321-00018 (Oct. 7, 2019); *Planet Labs Inc. – Grant*, IBFS File No. SAT-MOD-20170713-00103 (July 19, 2018).

25 With +/- 30 km variations in apogee and perigee, SpaceX's Third Modification also raises safety concerns due to collision risk between its own constellation shells.

26 *See Space Exploration Holdings, LLC Request for Modification of the Authorization For the SpaceX NGSO Satellite System*, Memorandum Opinion and Order, DA 20-588 at ¶ 20 (rel. June 4, 2020) ("*First Modification Reconsideration Order*") ("Our rules do not prohibit SpaceX's selection of an orbital regime that is also used by other satellite operators.") (quoting *First Modification Grant*, at ¶ 22); *Mitigation of Orbital Debris in the New Space Age*, Report and Order and Further Notice of Proposed Rulemaking, 35 FCC Rcd 4156, ¶ 15 (2020) ("*Mitigation of Orbital Debris Report and Order and FNPRM*") ("[Public interest] provisions of the [Communications] Act have remained unchanged since the Commission's previous analysis of its authority in this area, in which it concluded that orbital debris and related mitigation issues are relevant in determining whether the public interest would be served by authorization of any particular satellite-based communications system."); *see also Mitigation of Orbital Debris*, Second Report and Order, 19 FCC Rcd 11567, ¶¶ 13, 14 (2004) (finding that "orbital debris mitigation issues are a valid public interest consideration in the Commission's licensing process," and "[b]ecause orbital debris could affect the cost, reliability, continuity, and safety of satellite

it has not yet created such rules requiring large NGSO constellation separation because it expected NGSO operators would themselves ensure such separation given its importance to space safety,[27] which SpaceX has not done in its Third Modification. The collision risk posed by the addition of a constellation in the same orbital altitude region as another constellation can be significant, resulting in additional conjunction events.

operations, orbital debris issues have a bearing upon the 'larger and more effective use of radio in the public interest'").

[27] *See Mitigation of Orbital Debris Report and Order and FNPRM*, at ¶ 47 ("[W]hile we are concerned about the risk of collisions between the space stations of NGSO systems operating at similar orbital altitudes, as the Commission has previously stated, we think that these concerns are best addressed in the first instance through inter-operator coordination.").

Figure 1: Separation between the Kuiper System and SpaceX before Third Modification

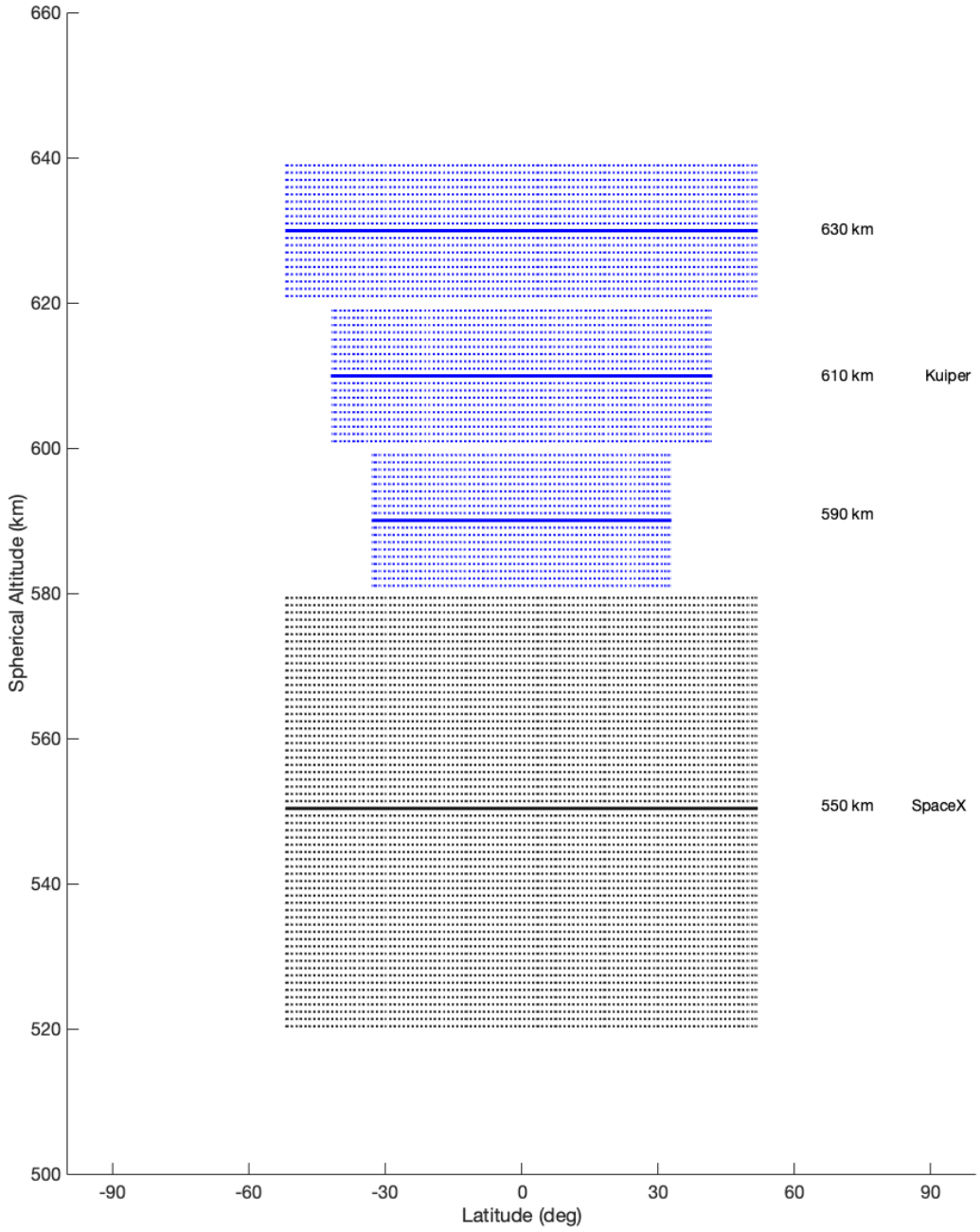
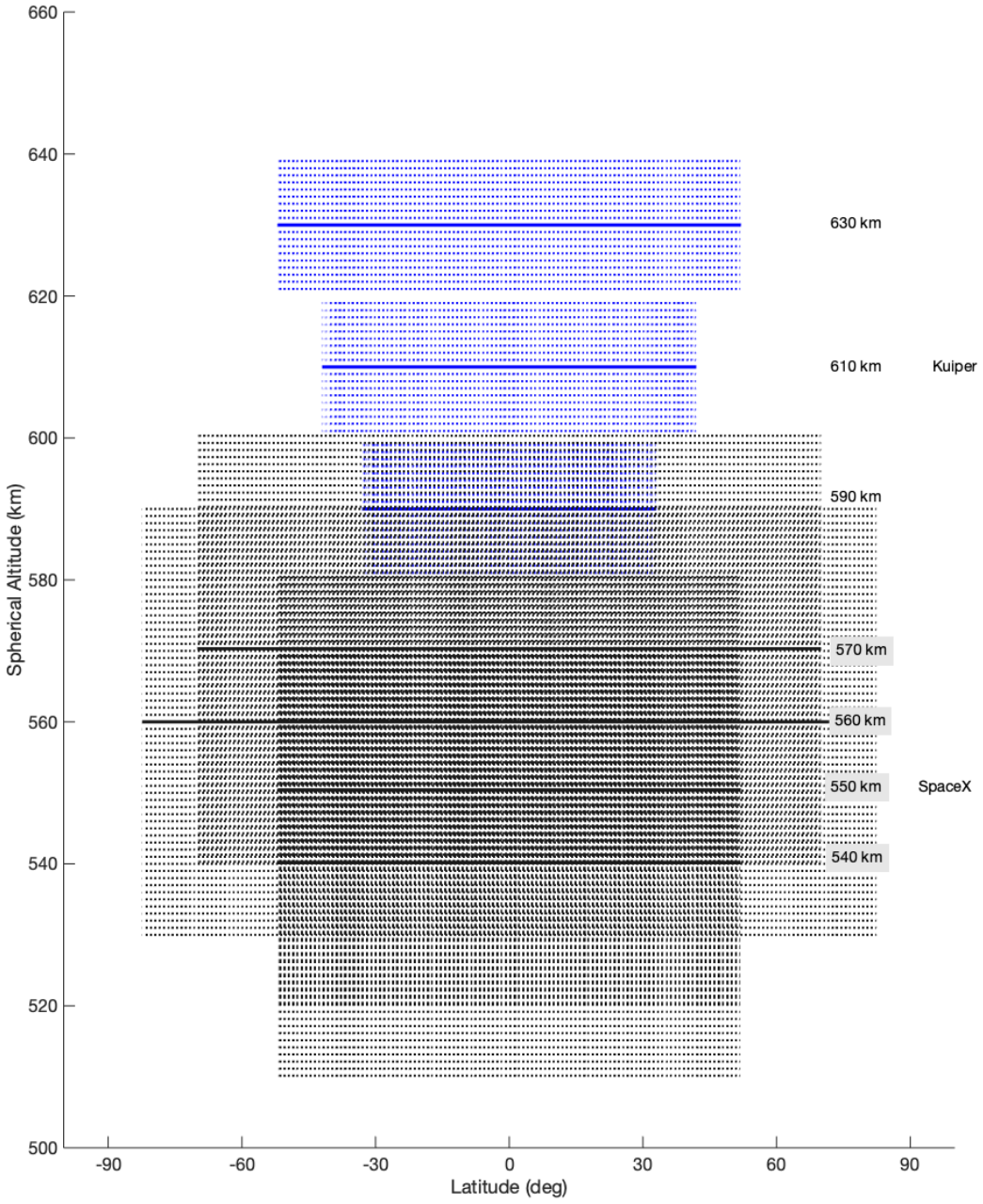


Figure 2: SpaceX Overlap with the Kuiper System after Third Modification



Amazon's analysis of the Third Modification shows the addition of 1,240 SpaceX satellites at 560 and 570 km altitudes when combined with the Kuiper System's 784 satellites at 590 km, results in an average of 509 daily conjunction events of close approach distance less than 1 km between the two constellations, as shown in Figure 3.[28] This is more than an order of magnitude increase when compared to the Kuiper System's expected 32 daily conjunction events due to the existing orbit debris catalog.

Figure 3: Daily Incremental Close Approaches to the Kuiper System

Case	Events per day < 1 km	Events per day < 500 m	Events per day < 250 m
Current Debris Catalog	32	8	3
SpaceX Inclination = 97.6° Altitude = 582 km[29]	243	92	21
SpaceX Inclination = 70° Altitude = 590 km[30]	266	102	28
Total	541	202	52

The additional burden adds complexity to risk-mitigation operations and also requires propulsion resources. The number of high-risk conjunctions that occur when large constellations are located in the same orbit region have the potential to challenge safety practices. Yet, SpaceX fails to even acknowledge the newly created orbital overlap with the Kuiper System, claiming only that its Third Modification will "increas[e] the space between SpaceX's satellites and other

[28] This analysis used a particular orbital configuration within SpaceX's large orbit region allowance, based on publicly available data in Commission filings.

[29] This is the altitude amidst the ranges of the filing that produced the worst-case conjunction events for the 96.7 degree inclination orbit.

[30] This is the altitude amidst the ranges of the filing that produced the worst-case conjunction events for the 70 degree inclination orbit.

proposed large NGSO constellations, such as OneWeb and Telesat."[31] In its Third Modification, SpaceX recognizes that increasing spacing between large NGSO constellations is in the public interest when vacating the 1,150 to 1,325 km altitude.[32] It is this same public interest that is now harmed when SpaceX moves to 540 to 570 km (+/- 30 km) and overlaps with the Kuiper System.[33]

Indeed, the International Bureau has already requested information from SpaceX on "the efforts that have been taken or will be taken to address collision risk with respect to other satellite systems licensed or applying for licenses to be operated at the same operational altitude ranges, including any coordination of operations that has occurred or that is planned."[34] SpaceX's response to this request omits any mention of coordination with the Kuiper System's planned operations at 590 km +/- 9 km, which has been publicly known since July 4, 2019.[35] SpaceX should have included the Kuiper System in its response because SpaceX proposes to operate

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31 *See Third Modification*, at 7. As noted in Amazon's May 1, 2020 *ex parte* letter, the Commission needs more information about how SpaceX "will accommodate spacecraft transiting through the system and other systems, large or small, operating in the same region." Letter from Mariah Dodson Shuman, Corporate Counsel to Kuiper Systems LLC, to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-MOD-20200417-00037 (filed May 1, 2020) (quoting *Mitigation of Orbital Debris Report and Order and FNPRM*, ¶ 48). The Commission also needs a certification that SpaceX's satellites "will have a unique telemetry marker allowing it to be distinguished from other satellites or space objects." *Mitigation of Orbital Debris Report and Order and FNPRM*, at ¶ 64.

32 *See Third Modification*, at 3, 7.

33 In response to a concern raised by Kepler, the FCC previously considered space safety when SpaceX first sought authority to operate some satellites at 550 km. *See* Letter from Nickolas G. Spina, Counsel to Kepler Communications, Inc., to Marlene H. Dortch, Secretary, FCC, IBFS File Nos. SAT-MOD-20181108-00083, SAT-MOD-20190830-00087, and SAT-STA-20190924-00098, at 7 (filed Oct. 15, 2019). In that case, there was no overlap with the Kepler system, which at the time included 140 satellites planned for 600 km. *First Modification Reconsideration Order*, at ¶ 19. In contrast, Amazon's constellation includes a total of 3,236 satellites, more than twenty-three times as many satellites as Kepler, with 784 of those satellites likely to overlap with SpaceX's proposed modification. *The Kuiper System Application*, at 2.

34 *IB Letter*, at 1.

35 *See SpaceX Response*; *see also The Kuiper System Application*.

satellites at some of the same orbital altitudes as the Kuiper System when orbital tolerance is taken into consideration. SpaceX's response to the FCC's request for information on systems at the "operational altitude ranges" should have included all U.S. and non-U.S. satellites licensed or granted market access by the FCC or with pending applications for such authority that would operate at altitudes impacted by SpaceX satellites' +/- 30 km orbital tolerance (i.e., 510 km to 600 km). SpaceX, however, limited its response to operators authorized in 2016 and 2017 to serve the United States, U.S.-licensed cubesats at altitudes from 400 km and 650 km, and non-U.S. ITU filings with a perigee of 540-570 km.[36] This selective response fails to provide the information requested by the Commission on the efforts SpaceX will take to address collision risk with other satellite systems that "plan to be operated at the same operational altitude ranges"—such as the Kuiper System.[37]

In sum, the Commission should deny SpaceX's Third Modification as currently proposed because it harms the public interest in space safety. The additional conjunction events created by overlapping orbits of SpaceX's system redesign, exacerbated by reliability issues, increase collision risk to the Kuiper System. Alternatively, the Commission could condition grant on SpaceX maintaining a tighter orbital tolerance that would preclude overlap with the Kuiper System. Despite SpaceX's claim that it "has invested in advanced propulsion capabilities,"[38] satellites with propulsion can and indeed should maintain far tighter orbital tolerance than +/- 30 km, such as the Kuiper System constellation and the majority of other smaller constellations

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36 *See SpaceX Response*, at 3-4.
37 *IB Letter*, at 1.
38 *See Third Modification*, at 11.

operating in this orbital region.[39] Absent stricter tolerances on apogee and perigee control, the Commission should limit SpaceX's nominal altitude to no higher than 550 km. Doing so would account for the orbital tolerance proposed by both constellations and eliminate the possibility of orbital overlap with the Kuiper System.[40]

III. THE SPATIAL CONFIGURATION PROPOSED IN THE SPACEX THIRD MODIFICATION ADVERSELY IMPACTS THE RF INTERFERENCE ENVIRONMENT FOR OTHER CO-FREQUENCY SYSTEMS, INCLUDING THE KUIPER SYSTEM.

SpaceX inaccurately claims that its Third Modification would "maintain—or even improve—the interference environment."[41] In fact, the Third Modification a) causes a significant increase in the frequency and total duration of in-line events with other NGSO FSS systems, b) increases the interference between SpaceX and other NGSO FSS systems, and c) detrimentally impacts the operation of other NGSO FSS systems as a result of the increased interference.

A. SpaceX's Third Modification causes more in-line interference events.

The chart in Figure 4 reflects the changes in orbital parameters between the Third Modification and SpaceX's initial license:

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[39] *See, e.g.*, Letter from Elisabeth Neasmith, Director, Spectrum Management and Development, Telesat, to Jose P. Albuquerque, Chief, Int'l Bureau, FCC, at 4 (filed Apr. 14, 2017) (orbital tolerance of +/- 300m); DG Consents Sub, Inc. Application for Modification of License, IBFS File No. SAT-MOD-20180918-00073 at 5 (filed Sept. 18, 2018) (orbital tolerance of +/- 2 km); GeoEye License Corp. Application for Modification of License, IBFS File No. SAT-MOD-20120427-00079 at A-2 (filed Apr. 27, 2012) (now licensed by DG Consents Sub, Inc.) (orbital tolerance of +/- 8 km); BlackSky Global LLC Application for Modification of License, IBFS File No. SAT-MOD-20190802-00070 at 6 (filed Aug. 2, 2019) (orbital tolerance of +/- 10 km); Ex Parte of Kinéis, IBFS File No. SAT-PDR-20191011-00113 at 2 (filed Jan. 13, 2020) (orbital tolerance of +/- 10 km expected).

[40] Due to the significant numbers of satellites involved, the public interest requires that large constellations should be configured in such a way as to minimize the risk of conjunction events. Specifically, the nominal orbital altitude of large constellations should be separated by the relevant orbital tolerances in order to minimize the risk of conjunction events.

[41] *Third Modification*, at 9.

Figure 4: Changes in Orbital Parameters[42]

	# Satellites per Gateway	Elevation Angles	Altitudes
Original License	4	Minimum of 40 degrees[43]	1,110 km 1,130 km 1,150 km 1,275 km 1,325 km[44]
First and Second Modification	4[45]	Minimum of 40 degrees, nominally [46]	550 km 1,110 km 1,130 km 1,275 km 1,325 km[47]
Third Modification	8[48]	User beams: minimum of 25 degrees[49] Gateway beams: general minimum of 25 degrees; minimum of 5 degrees for 560 km and 570 km shells for gateways above 62 degrees latitude[50]	540 km 550 km 560 km 570 km[51]

42 *See Third Modification*, at Technical Information, 2 ("SpaceX requests no other technical changes to its authorization at this time, and certifies that all other technical information provided in its previous Ku/Ka-band applications, as modified, remains unchanged.").

43 *SpaceX Application*, at 6.

44 *Id.*

45 *First Modification*, at Technical Information, 8 ("Up to four satellites can beam transmissions to the gateway location.").

46 *First Modification*, at Technical Information, 5 ("To maintain suitable coverage during the very early stages of initial deployment, SpaceX may periodically use a minimum elevation angle as low as 25 degrees for this initial shell. Then, as further satellites are deployed to populate the remainder of the constellation, SpaceX will revert to a 40 degree minimum elevation angle for all user and gateway beams.").

47 *First Modification*, at Technical Information, 5, 2.

48 *Third Modification*, at Technical Information, 8.

49 *Third Modification*, at 4.

50 *Id.* at 7.

51 *Id.* at 4.

These changes are not trivial. Rather, they fundamentally alter the interference environment, in terms of interference to the Kuiper System and other NGSO FSS systems and in terms of SpaceX's susceptibility to interference from other systems.[52]

In the Third Modification, SpaceX claims that, "[b]ecause the proposed modification will slightly decrease the total number of satellites (from 4,409 to 4,408) and relocate many of them to operate at lower altitude, fewer of them will be visible above the minimum elevation angle at any particular time throughout the United States."[53] In its analysis, however, SpaceX fails to consider how the distribution of satellites affects the interference environment. The Third Modification would cause a substantial change in how active satellites are distributed with respect to earth station location and elevation angle. For other co-frequency NGSO FSS systems, this change produces more in-line events and reduces network availability, as explained below.

There are four interference scenarios to consider between NGSO FSS systems with directional antennas – two uplink and two downlink scenarios as shown in Figure 5.[54] In the two downlink interference scenarios, the receive separation angle between the satellites involved (θ_R),

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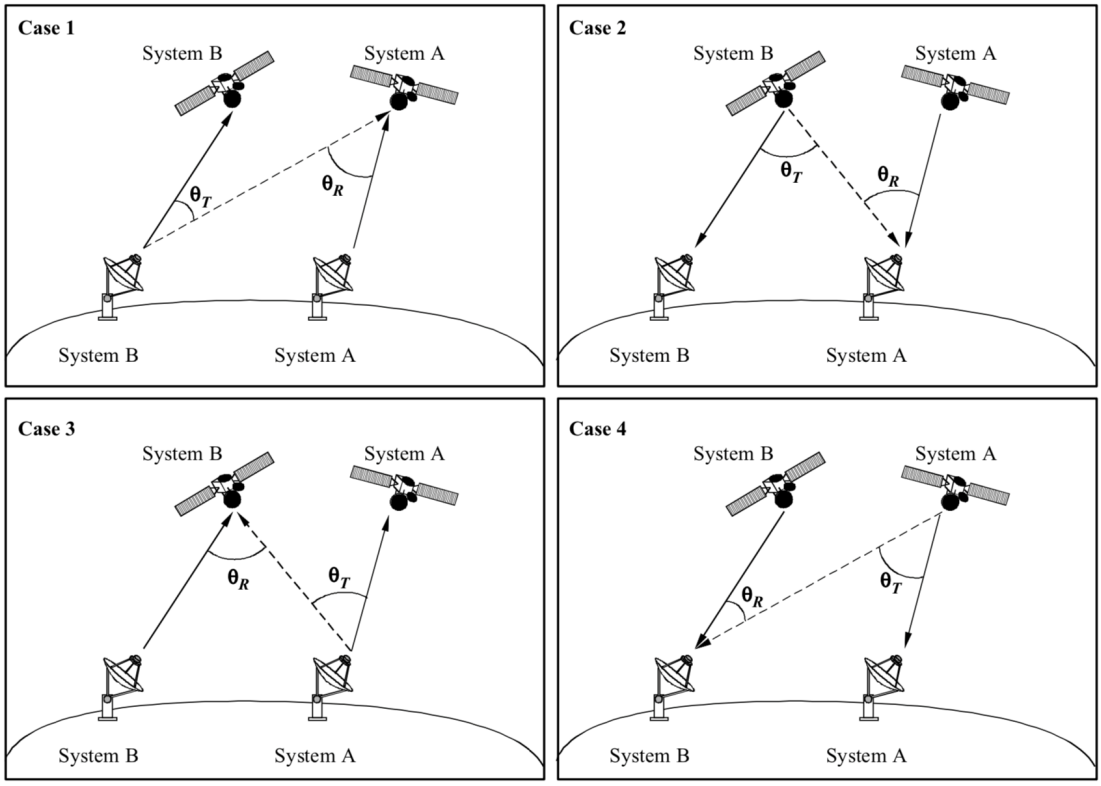
[52] SpaceX itself has recognized that reducing the minimum elevation for an NGSO system has a substantial impact on the interference environment, as they recently protested a similar maneuver by OneWeb/WorldVu. *See* Ex Parte of Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20180319-00022, at 1 (filed May 11, 2020) ("Operating at lower elevation angles will enable each OneWeb gateway earth station to communicate with more satellites - but will also potentially bring significantly more satellites into its field of operations, increasing the potential for harmful interference. Accordingly, [SpaceX] requests that the Commission dismiss OneWeb's application, or at a minimum immediately require OneWeb to amend its application to reflect its intended operations at lower elevation angles and submit the technical analysis necessary to demonstrate that it can operate the proposed system at reduced elevation angle [sic] not anticipated in its current authorization without interfering with SpaceX or any other NGSO FSS or geostationary orbit ('GSO') system.").

[53] *Third Modification*, at Technical Information, 16.

[54] *See* Int'l Telecomm. Union [ITU], Recommendation ITU-R S.1526, *Definition of a non-geostationary-satellite orbit fixed-satellite service system interference environment metric for co-directional frequency sharing between two non-geostationary-satellite orbit fixed-satellite service systems*, at 3, Fig. 1 (2001) (providing graphical guidance on four interference scenarios).

from the viewpoint of the victim earth station, is a critical component of interference-to-noise (I/N) and carrier-to-interference (C/I) computations. In the uplink interference scenarios, the transmit separation angle (θ_T), from the viewpoint of the interfering earth station, is likewise an important factor in interference computations. When the two systems' earth stations are co-located, θ_R is zero in the two uplink interference scenarios (Case 1 and Case 3), and θ_T is zero in the two downlink interference scenarios (Case 2 and Case 4). In-line events occur between NGSO FSS systems when these angles fall below a pre-determined threshold, such that there is a risk of main-beam-to-main-beam interference. In-line *interference* events may occur between the NGSO FSS systems when both systems are actively communicating with co-located or nearby earth stations in the same frequency and polarization at the time of the in-line event.

Figure 5: Interference Cases



Amazon performed analysis to determine the change in number of in-line interference events and the total duration of in-line events due to the Third Modification. Figure 6 below shows the Third Modification increases the number and duration of in-line events with the Kuiper System, as well as three other authorized NGSO FSS systems. This is true when considering all in-view satellites of each constellation, and when randomly selecting "active" satellites from each constellation. The Figure 6 analysis considered three in-line event threshold separation angles: 5, 10, and 15 degrees, and shows the percentage increase in number and duration of in-line events. The in-line event threshold separation angles were maintained for the before and after Third Modification analysis scenarios, even though SpaceX's lower altitude causes a higher uplink I/N into its system and requires larger separation angles. Figure 7 shows that, when randomly choosing active satellites, the total number and duration of in-line interference events for Kuiper System gateway links increase for all threshold separation angles and gateway latitudes. Similar impacts can be seen for the other NGSO FSS systems as well.

Figure 6: Increase in Number of In-Line Events and Total Duration of In-Line Events with NGSO FSS Systems Under SpaceX's Third Modification

% Change in Number of Inline Events - Considering All In-View Satellites					
		Kuiper Gateways	O3b	OneWeb	Telesat
In-Line Event Threshold Separation Angle [degrees]	Earth Station Latitude [deg N]	% Change	% Change	% Change	% Change
5	25	137%	115%	146%	135%
	35	92%	83%	122%	66%
	45	49%	29%	128%	126%
10	25	126%	258%	160%	129%
	35	78%	191%	129%	74%
	45	39%	27%	134%	141%
15	25	95%	487%	146%	127%
	35	59%	186%	109%	82%
	45	32%	33%	114%	156%

% Change in Aggregate Duration of Inline Events - Considering All In-View Satellites					
		Kuiper Gateways	O3b	OneWeb	Telesat
In-Line Event Threshold Separation Angle [degrees]	Earth Station Latitude [deg N]	% Change	% Change	% Change	% Change
5	25	175%	72%	127%	124%
	35	127%	46%	92%	28%
	45	105%	-3%	105%	112%
10	25	152%	94%	125%	118%
	35	102%	69%	93%	28%
	45	81%	1%	108%	118%
15	25	113%	214%	114%	108%
	35	72%	58%	83%	32%
	45	59%	7%	100%	127%

Figure 7: Increase in Number of In-Line Interference Events and Total Duration of In-Line Interference Events with NGSO FSS Systems Under SpaceX's Third Modification, with Randomly Selected Active Satellites

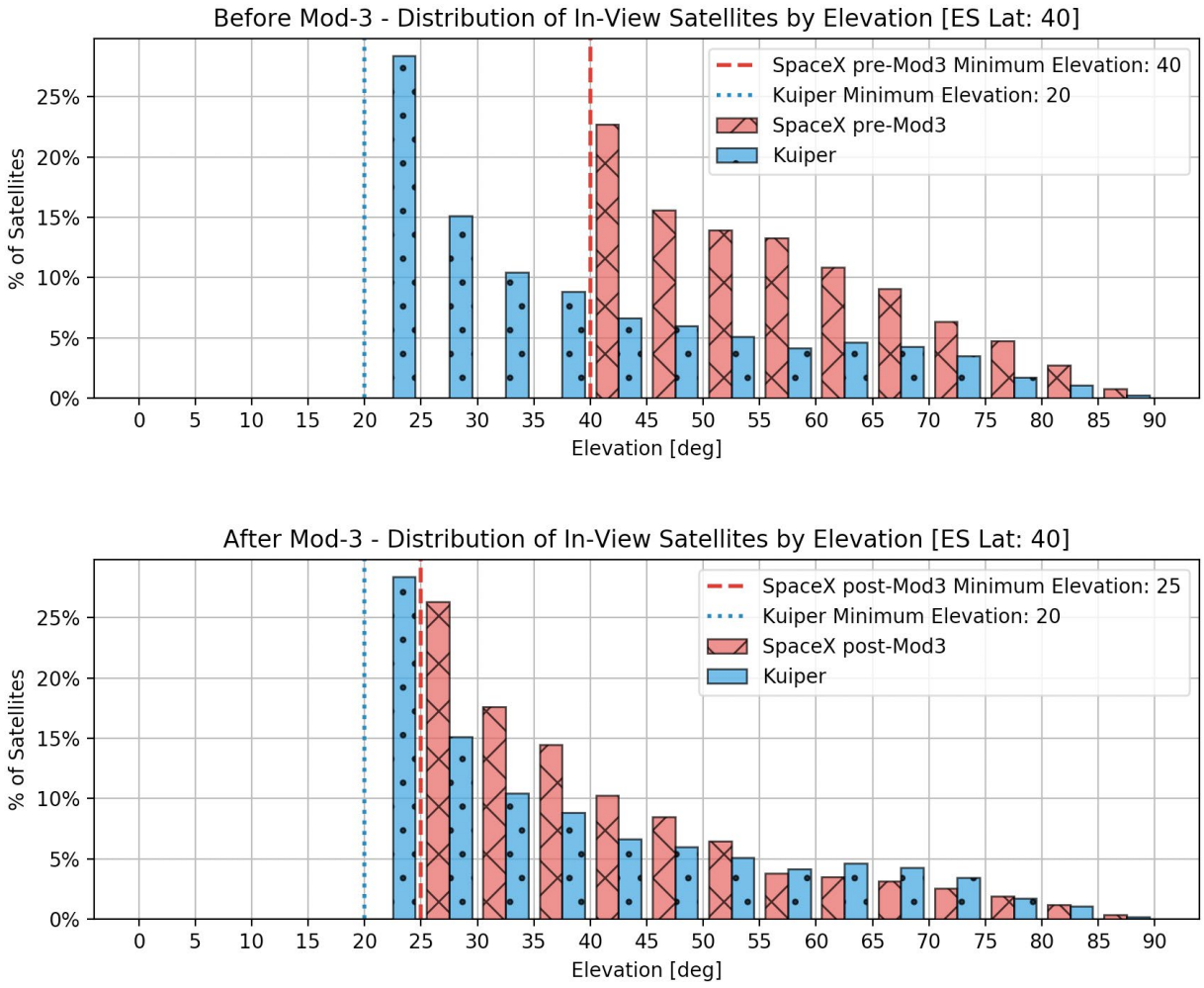
% Change in Number of Inline Interference Events - Considering Randomly Selected Active Satellites					
		Kuiper Gateways	O3b	OneWeb	Telesat
In-Line Event Threshold Separation Angle [degrees]	Earth Station Latitude [deg N]	% Change	% Change	% Change	% Change
5	25	180%	18%	361%	305%
	35	237%	197%	301%	166%
	45	292%	21%	215%	227%
10	25	197%	88%	361%	229%
	35	278%	168%	287%	144%
	45	350%	22%	200%	232%
15	25	198%	232%	326%	196%
	35	293%	143%	256%	128%
	45	377%	30%	186%	230%

% Change in Aggregate Duration of Inline Interference Events - Considering Randomly Selected Active Satellites					
		Kuiper Gateways	O3b	OneWeb	Telesat
In-Line Event Threshold Separation Angle [degrees]	Earth Station Latitude [deg N]	% Change	% Change	% Change	% Change
5	25	149%	-21%	290%	285%
	35	195%	169%	242%	130%
	45	308%	10%	179%	240%
10	25	132%	3%	275%	244%
	35	181%	153%	230%	128%
	45	265%	26%	167%	243%
15	25	113%	90%	243%	199%
	35	164%	130%	208%	123%
	45	227%	43%	159%	247%

A major reason for the increase in the number and duration of in-line events shown above is that the Third Modification proposes to lower the minimum elevation angle for SpaceX gateways from 40 degrees to 25 degrees, close to that of Kuiper System gateways at 20 degrees. At any point in time, the majority of Kuiper System satellites will be visible below 40-degree elevation for a given earth station. Prior to SpaceX's Third Modification, the Kuiper System and other Ka-band spectrum operators could rely on the fact that SpaceX would not operate below 40-degree elevation and there would be no in-line interference events with SpaceX satellites operating below 40-degree elevation. With this latest modification, over half of SpaceX's in-view satellites

would be below 40-degree elevation, requiring other Ka-band spectrum operators whose minimum elevation angles are below 40 degrees to contend with more in-line events. This increases the interference between SpaceX and other NGSO FSS systems and restricts coordination options based on diversity of elevation angles. This change is illustrated in Figure 8.

Figure 8: Percentages of Satellites by Elevation Angle



Additionally, with the Third Modification, SpaceX has doubled the number of active satellites communicating with its gateway earth stations. The combination of changes proposed in the Third Modification that bring more active satellites into the field of operations of other NGSO FSS systems will impact the NGSO FSS interference environment, as demonstrated below.

B. The Third Modification increases the interference to the Kuiper System and SpaceX's susceptibility to interference from other NGSO FSS systems.

The above analysis shows that SpaceX's Third Modification increases the number of in-line events and total duration of in-line events between SpaceX and other NGSO FSS Ka-band systems, including the Kuiper System. This is true when considering all in-view satellites and randomly selected "active" satellites. Despite the increase in in-line events between SpaceX and other NGSO FSS systems, SpaceX claims that "the modification would have no material effect on the interference environment of other NGSO systems."[55] To reach this conclusion, SpaceX makes several conceptual assumptions that do not properly reflect the actual interference environment.

1. The Third Modification increases SpaceX's susceptibility to interference.

SpaceX only demonstrates the interference effects with SpaceX in the interferer role. The Commission has stated previously that, in analyzing the interference effects of a modification, the Commission "must examine not only the potential for increased interference to other NGSO FSS systems as a result of SpaceX's modified operations, but also whether SpaceX's own system may become more susceptible to interference from other NGSO FSS systems, which would change the operating environment."[56] In the FCC's recent Memorandum Opinion and Order related to SpaceX's First Modification request, it disagreed with OneWeb's analysis that evaluation of susceptibility to interference should solely be determined by a static I/N analysis, instead noting that the frequency and duration of in-line events, and the total percentage of time during which a given level of interference is exceeded, should be considered.[57] Here, we show that SpaceX's Third Modification increases the frequency and duration of in-line events.

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55 *Third Modification*, at Technical Information, 16.
56 *First Modification Grant*, at ¶ 14.
57 *First Modification Reconsideration Order*, at ¶ 11.

Analyzing the cumulative distribution of interference-to-noise experienced by the SpaceX system from other NGSO FSS systems, such as the Kuiper System, shows that the interference to SpaceX is significantly increased due to the changes proposed in the Third Modification. Figure 9 shows the distribution of I/N received by SpaceX satellites from Kuiper System gateway uplinks, before (solid blue) and after (dashed orange) the Third Modification. Figure 10 shows the distribution of I/N received by SpaceX earth stations from Kuiper System satellite downlinks, before (solid blue) and after (dashed orange) the Third Modification. In both cases, there is a significant increase in the percentage of time for which any level of interference occurs.

Figure 9: Distribution of I/N Received by SpaceX Satellites from Kuiper System Gateway Uplinks, Before and After Third Modification

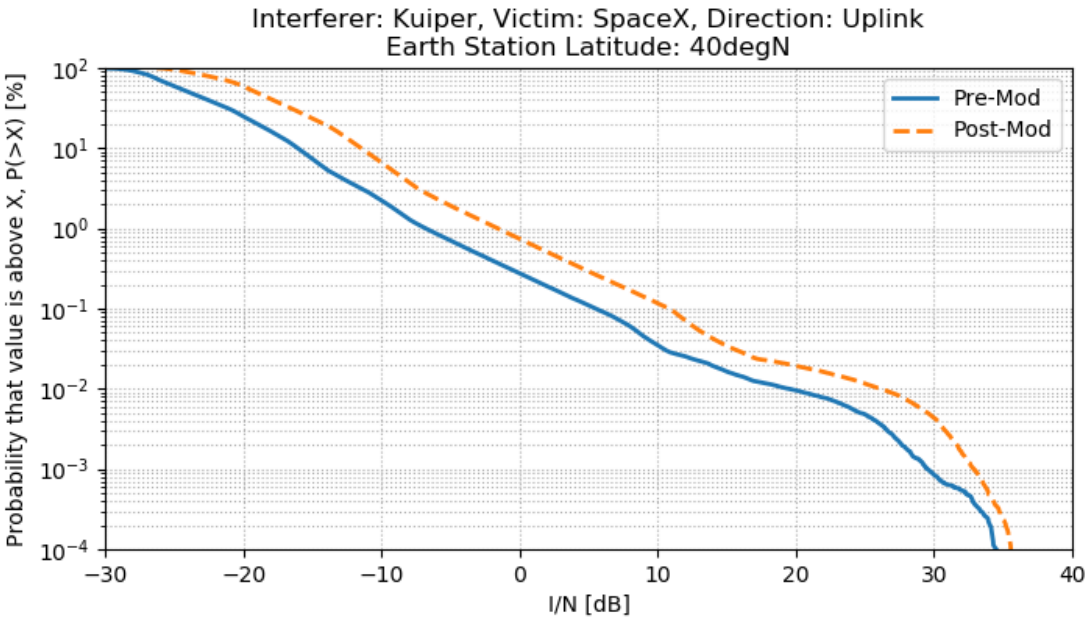
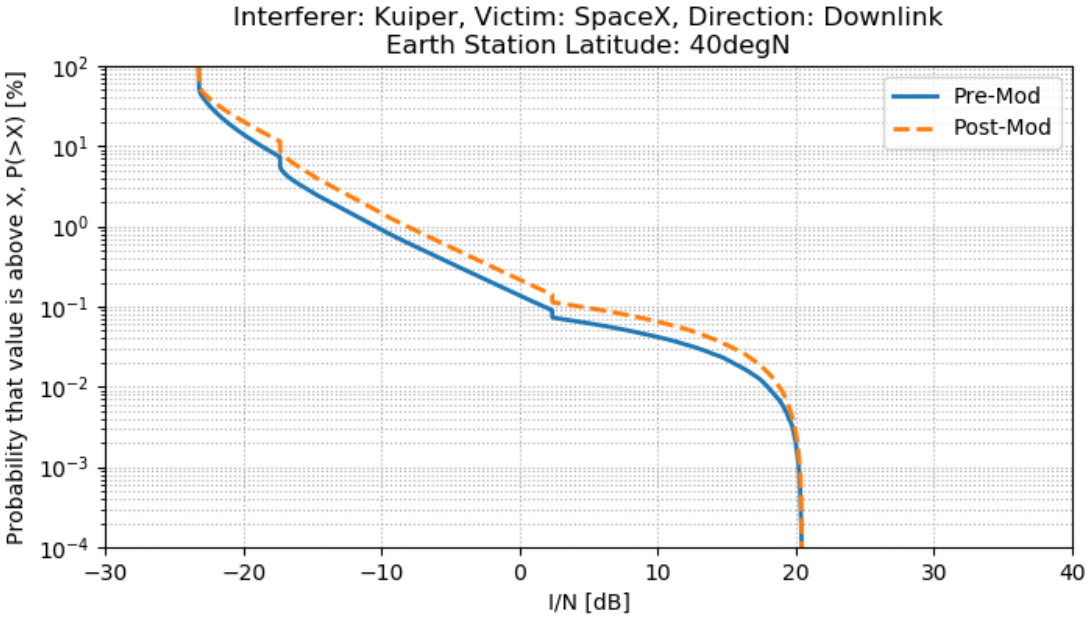


Figure 10: Distribution of I/N Received by SpaceX Earth Stations from Kuiper System Satellite Downlinks, Before and After Third Modification



2. The Third Modification increases interference into the Kuiper System.

When attempting to demonstrate the interference that SpaceX causes to other NGSO FSS systems, SpaceX is noncommittal in describing the effect that the Third Modification has on uplink interference. SpaceX says it "will be able to transmit and receive at lower EIRP levels,"[58] but it does not commit to doing so and does not provide a new uplink EIRP level for use in interference analysis. In its analysis of OneWeb's Petition to Reconsider SpaceX's first modification, the Commission declined to limit SpaceX's uplink transmissions beyond applicable $EPFD_{up}$ limits, which can be derived from uplink EIRP levels.[59] However, these limits are intended to protect GSO satellites from NGSO FSS earth station transmissions. They should not, therefore, be sufficient to draw a conclusion about NGSO-NGSO interference. If SpaceX were to leave its

58 *Third Modification*, at 10, 16.

59 *See First Modification Reconsideration Order*, at ¶ 14.

uplink EIRP unchanged, and is still allowed to transmit up to the $EPFD_{up}$ limits, the I/N levels from SpaceX into Kuiper System satellites would be increased for almost all time-percentiles, as Figure 11 shows.[60] This increased interference is caused by more interference events as a result of the lower elevation angles and increase in active satellites communicating with SpaceX earth stations.[61]

In the downlink direction, SpaceX commits to reducing its Ka-band downlink PFD from -116.3 to -123.3 dBW/MHz.[62] Even with the reduced PFD, the Third Modification results in higher probabilities of certain I/N levels (approximately 12 to 22 dB) from SpaceX into the Kuiper System downlinks, as shown in Figure 12.

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[60] If, however, SpaceX were to reduce its uplink EIRP, then the SpaceX uplink C/I with respect to other systems would be reduced. As the Commission stated with respect to the First Modification: "The lowering of the operational altitudes of SpaceX's satellites will result in the transmissions from earth stations of other NGSO FSS systems reaching SpaceX's satellites at a higher power level because of less spreading losses between the earth station and the satellites at closer distances than previously proposed. If SpaceX lowered the transmission power of its own earth stations to take advantage of the closer operational altitude of its modified satellites, then its satellites would be more susceptible to interference from the transmissions of earth stations communicating with other NGSO FSS systems in the same frequency band." *First Modification Grant*, at ¶ 15.

[61] To calculate SpaceX uplink interference, Amazon used SpaceX's earth station input power density of -19.7 dBW/MHz and a typical antenna gain of 49.5 dBi. *See, e.g.*, Space Exploration Holdings, LLC Application for Litchfield, CT Gateway Earth Station, IBFS File No. SES-LIC-20200410-00399, at 7 n.16, FCC 312 Main Form at E41/42 (filed Apr. 9, 2020); Space Exploration Holdings, LLC Application for Slope County, ND Gateway Earth Station, IBFS File No. SES-LIC-20200422-00442, at 7 n.16, FCC 312 Main Form at E41/42 (filed Apr. 21, 2020); Space Exploration Holdings, LLC Application for Nemaha, NE Gateway Earth Station, IBFS File No. SES-LIC-20200417-00422, at 7 n.16, FCC 312 Main Form at E41/42 (filed Apr. 17, 2020).

[62] There appears to be an inconsequential arithmetic error in Table A.7-2 of SpaceX's Third Modification Technical Attachment. The EIRP/1 MHz value is distorted by 4 dB.

Figure 11: SpaceX Gateway Uplink Interference into Kuiper System Satellite Gateway Link Satellite Receiver

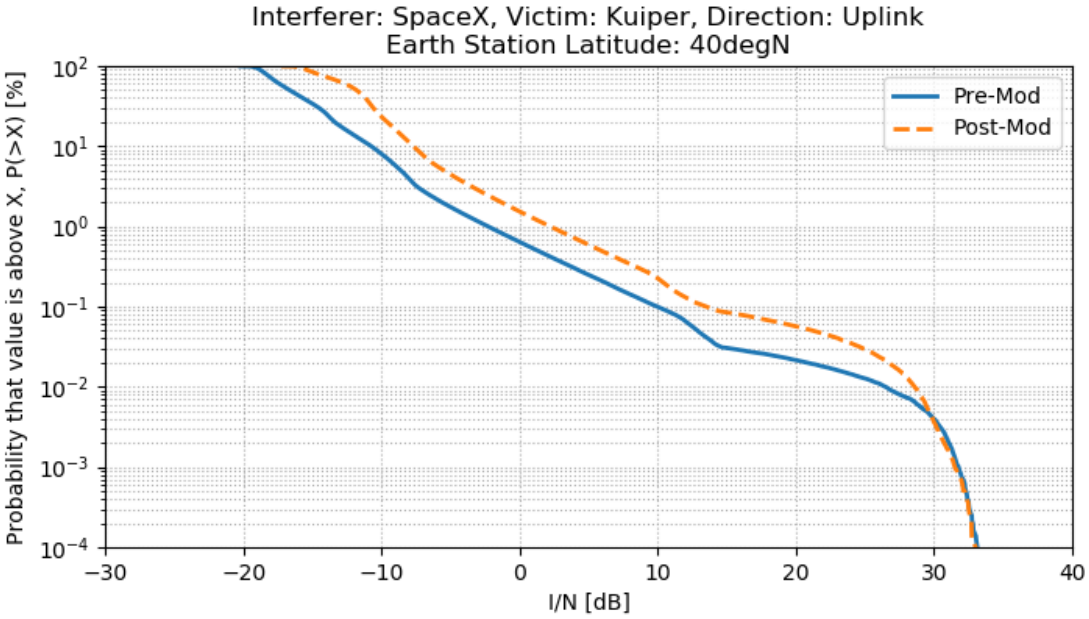
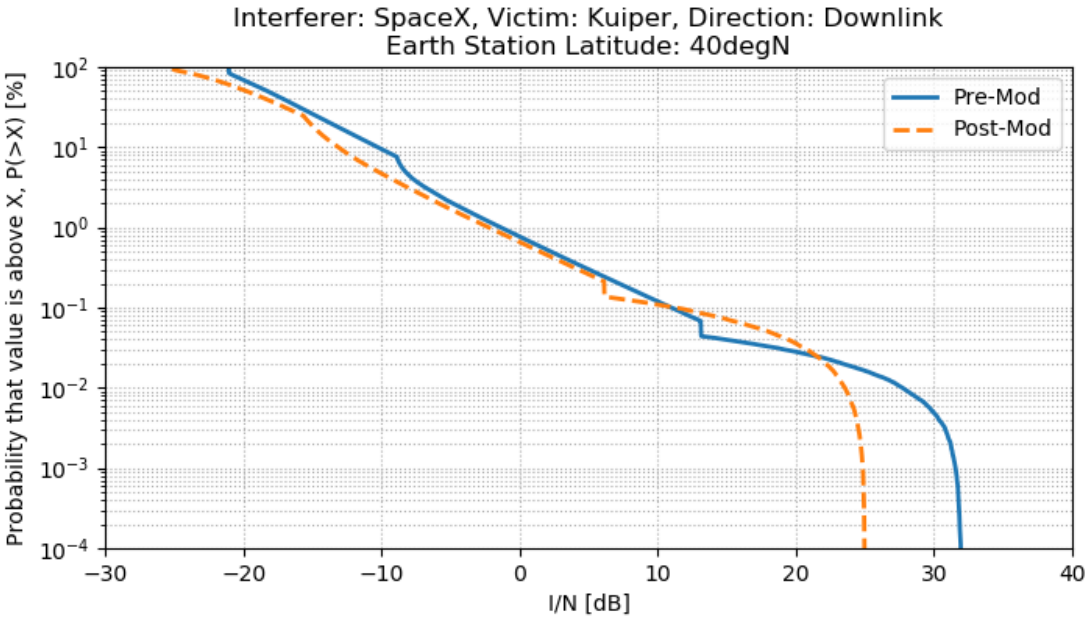


Figure 12: SpaceX Gateway Downlink Interference into Kuiper System Gateway Earth Station



In summary, SpaceX's Third Modification definitively worsens the interference in the first three of four interference scenarios depicted in Figures 9 through 11, and worsens the interference for some percentages of time in the last scenario, as shown in Figure 12. Thus, the Third

Modification not only increases the number and duration of in-line events, it also increases statistical interference levels.

C. The increase in interference events would have an operational impact to the Kuiper System.

As demonstrated in Section III.A, the frequency and duration of in-line interference events increase as a result of the Third Modification. This, combined with SpaceX's higher susceptibility to I/N from other systems' uplinks, and the doubling of its active satellites per ground station location, significantly impacts any co-frequency NGSO FSS system. In particular, this impact manifests itself in significant reductions in Kuiper System satellite availability to its gateways.

To demonstrate the effect the Third Modification has on the Kuiper System's operations, Amazon performed an analysis of the number of available Kuiper System satellites under various sharing scenarios with SpaceX. Satellite availability is a key metric for an NGSO FSS operator that drives the operator's ability to meet quality-of-service objectives, including network capacity and handover efficiency. This is especially true when applying availability analysis to gateway links, which are each individually responsible for supporting service to large numbers of customers.

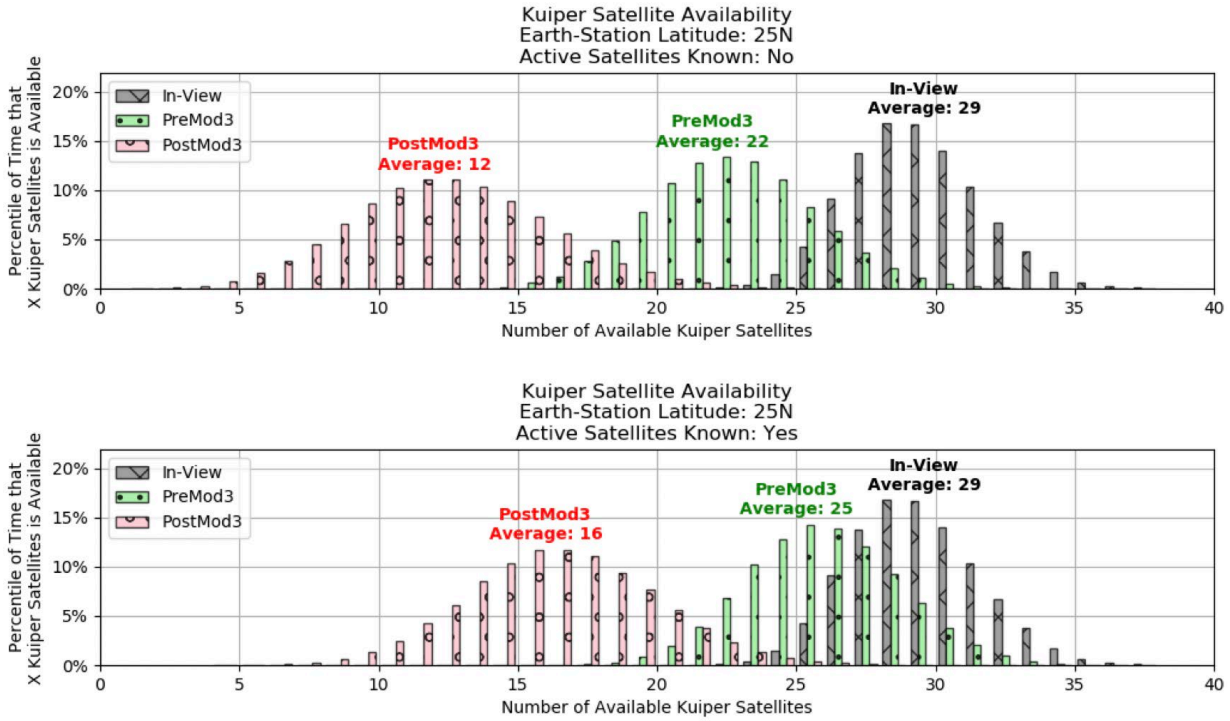
Amazon performed the analysis across a variety of earth station latitudes.[63] In every case, the number of available Kuiper System satellites was impacted. For example, the distribution of available Kuiper System satellites for an earth station at 25N latitude shows the median number of available satellites is nominally 29, when not considering resolving in-line events with SpaceX. Once SpaceX's as-authorized system is included in the simulation, the median number of available Kuiper System satellites is 22. SpaceX's Third Modification would cause a decrease in available

[63] Amazon computed necessary avoidance angles using a 6% dT/T threshold as well as 32-25*log(θ) earth station antenna patterns.

Kuiper System satellites, as shown in the large leftward shift in Figure 13 below. The median number of available satellites would be reduced from 22 to 12, and the minimum number of available Kuiper System satellites would be reduced from 15 to 3.

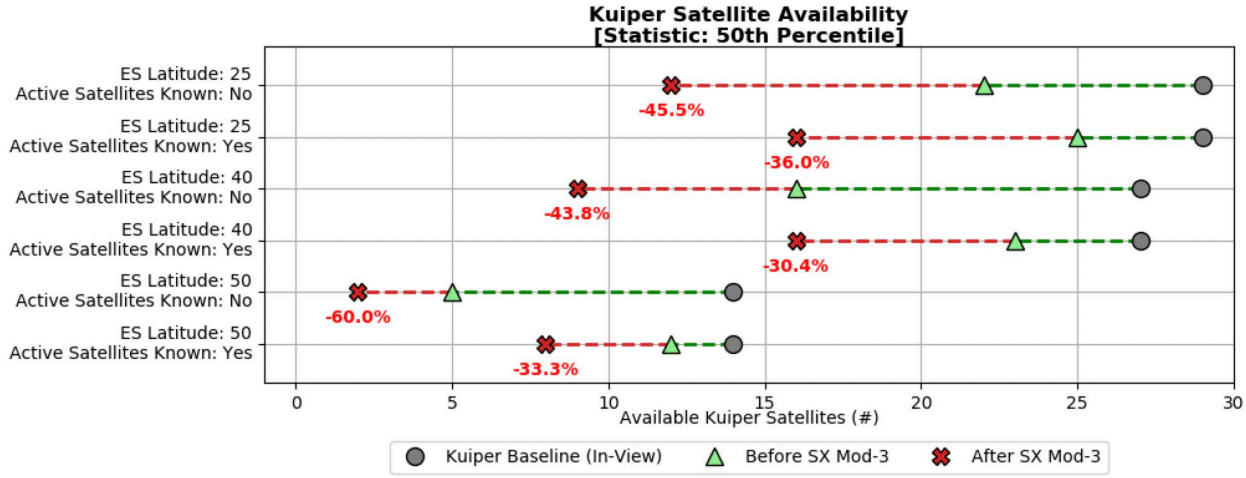
A similar effect is observed when simulating prior knowledge of SpaceX's satellite selection and beam positioning by randomly selecting "active" satellites. In that simulation, SpaceX's Third Modification would still have a large effect on the Kuiper System's operations, as the median number of available Kuiper System satellites decreases from 25 to 16 for an earth station at 25N.

Figure 13: Kuiper System Satellite Availability at 25N



This same effect is exhibited at a variety of earth station latitudes below in Figure 14 (*median* number of available Kuiper System satellites).

Figure 14: Median Kuiper System Satellite Availability at Various Earth Station Latitudes



As the analysis above demonstrates, SpaceX's Third Modification operationally harms the Kuiper System by reducing the number of Kuiper System satellites that would be available to earth stations at every latitude analyzed.

D. Following resolution of the space safety concerns warranting denial, the SpaceX constellation should be considered as part of the 2020 Processing Round.

Considering the entire SpaceX constellation as part of the 2020 Processing Round would be consistent with precedent and equitable with the FCC's processing of other NGSO FSS applications. On March 24, 2020, the Satellite Division of the FCC announced that it was initiating a "new processing round for additional applications and petitions for operations in the 10.7-12.7 GHz, 12.75-13.25 GHz, 13.85-14.5 GHz, 17.7-18.6 GHz, 18.8-20.2 GHz, and 27.5-30 GHz frequency bands by non-geostationary orbit fixed-satellite service (NGSO FSS) systems" (the "2020 Processing Round").[64] SpaceX filed the Third Modification while the 2020 Processing Round was ongoing. Action on SpaceX's Third Modification outside the 2020 Processing Round

64 *See March 24, 2020 Processing Round PN.*

would undermine that process by significantly altering the interference environment for other NGSO FSS operators.

As demonstrated above, operation of SpaceX's satellites as proposed in the Third Modification would collectively increase the quantity and duration of in-line events due to the increase in active SpaceX satellites in view of each gateway earth station and operation at lower altitudes and lower elevation angles. This would increase SpaceX's own susceptibility to interference, limit the network capacity and availability of other NGSO FSS systems, and increase interference to those systems. These effects, together with the effects of SpaceX's previous modifications as elucidated above, have a cumulative impact on the interference environment for other NGSO FSS operators.

Considering the entire SpaceX constellation as part of the 2020 Processing Round would also further the Commission's stated policy to allow for future entry by preserving regulatory certainty for prior applicants while still considering future applicants.[65] Conversely, allowing the Commission's license modification rules to be used to create a more burdensome environment for other systems would harm the Commission's stated goal of "provid[ing] a measure of certainty in lieu of adopting an open-ended requirement to accommodate all future applicants."[66] SpaceX's proposal would create a more challenging operating environment and therefore could, if considered separately from systems in the 2020 Processing Round, create increased barriers to

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65 *NGSO FSS Order*, at ¶ 61 ("[T]reatment of later applicants to approved systems must necessarily be case-by-case based on the situation at the time, and considering both the need to protect existing expectations and investments and provide for additional entry as well as any comments filed by incumbent operators and reasoning presented by the new applicant.").

66 *Id.*

competition and deter investment.[67] SpaceX's prior modification requests collectively, with this Third Modification, adversely impact the operating environment; accordingly, the entire SpaceX constellation should be considered in the 2020 Processing Round.

IV. CONCLUSION.

Amazon respectfully requests that the FCC deny SpaceX's Third Modification to ensure a safe orbital environment for all satellite operators. If space safety issues warranting denial can be resolved, Amazon requests that the Commission consider the entire SpaceX constellation as part of the 2020 Processing Round to provide regulatory certainty and ensure the stability of the interference environment.

Respectfully submitted,

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[67] The Commission has also noted that when an operator makes a significant change to its system, as SpaceX proposes to do here, "it would indicate that [the operator] has not made the kind of progress that would limit its flexibility to incorporate design changes into its system. In this case, sharing the burden equally with new entrants may not impede its progress in implementing its system." *Teledesic Corporation Petition for Clarification And/Or Reconsideration*, Memorandum Opinion and Order, 17 FCC Rcd 2489, ¶ 9 (2002). This further supports consideration of the entire SpaceX constellation in the 2020 Processing Round for purposes of spectrum sharing.

CERTIFICATE OF SERVICE

I hereby certify that, on this 13th day of July 2020, a copy of the foregoing pleading was served via First Class mail upon:

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